

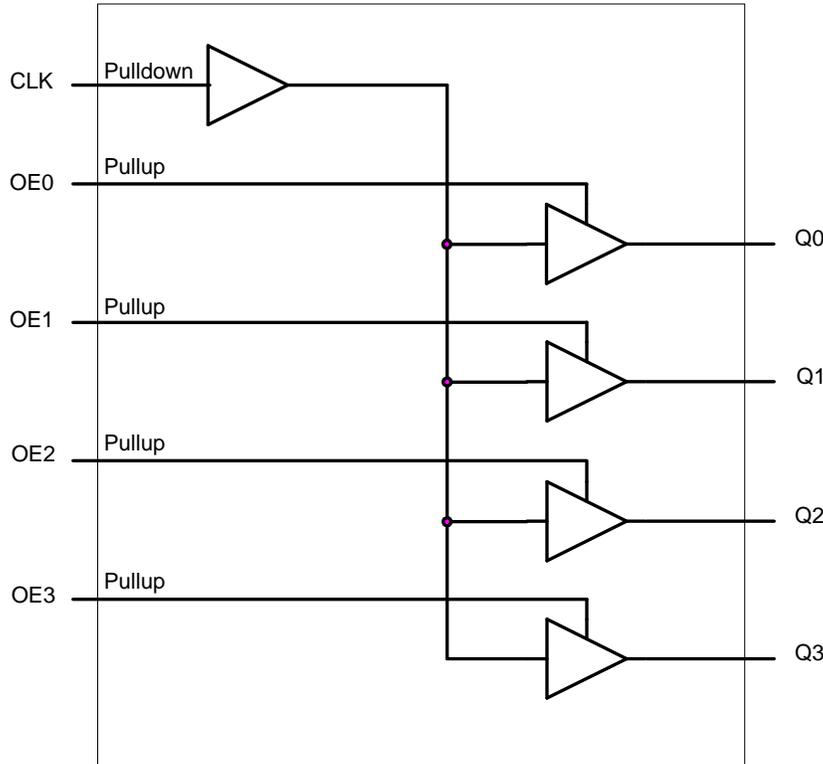
## General Description

The ICS8304-02 is a low skew, high performance, 1-to-4 Fanout Buffer with individual output enables. The ICS8304-02 is characterized at full 3.3V and 2.5V for input ( $V_{DD}$ ), and mixed 3.3V and 2.5V for output operating supply modes ( $V_{DDO}$ ). Guaranteed output and part-to-part skew characteristics make the ICS8304-02 ideal for those clock distribution applications demanding well defined performance and repeatability.

## Features

- Four LVCMOS / LVTTL outputs, 15Ω output impedance
- LVCMOS / LVTTL clock input
- Maximum output frequency: 250MHz
- Output skew: 30ps (typical)
- Part-to-part skew: 400ps (maximum)
- Small 16 lead TSSOP package saves board space
- Power supply modes:  
Core/Output  
3.3V/3.3V  
3.3V/2.5V  
2.5V/2.5V
- Individual output enable control
- 0°C to 70°C ambient operating temperature
- Available in lead-free (RoHS 6) packaging
- **For functional replacement part use 8305**

## Block Diagram



## Pin Assignment

OE0	1	16	OE3
OE1	2	15	nc
VDDO	3	14	GND
Q0	4	13	Q3
Q1	5	12	Q2
GND	6	11	VDDO
CLK	7	10	OE2
VDD	8	9	nc

**ICS8304-02**  
**16-Lead TSSOP**  
 4.4mm x 5.0mm x 0.92mm package body  
**G Package**  
 Top View

## Pin Descriptions and Pin Characteristics

**Table 1. Pin Descriptions**

Number	Name	Type		Description
1, 2, 10, 16	OE0, OE1, OE2, OE3	Input	Pullup	Output enable pins. Active HIGH. If pin is LOW, output is high impedance. LVCMOS/LVTTL interface levels. See Table 3.
3, 11	V <sub>DDO</sub>	Power		Output supply pins.
4, 5, 12, 13	Q0, Q1, Q2, Q3	Output		Single-ended clock outputs. 15Ω output impedance. LVCMOS/LVTTL interface levels.
6, 14	GND	Power		Power supply ground.
7	CLK	Input	Pulldown	Single-ended clock input. LVCMOS/LVTTL interface levels.
8	V <sub>DD</sub>	Power		Power supply pin.
9, 15	nc	Unused		No connect.

NOTE: *Pullup* and *Pulldown* refer to internal input resistors. See Table 2, *Pin Characteristics*, for typical values.

**Table 2. Pin Characteristics**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
C <sub>IN</sub>	Input Capacitance			4		pF
R <sub>PULLUP</sub>	Input Pullup Resistor			51		kΩ
R <sub>PULLDOWN</sub>	Input Pulldown Resistor			51		kΩ
C <sub>PD</sub>	Power Dissipation Capacitance (per output)	V <sub>DD</sub> , V <sub>DDO</sub> = 3.465V or 2.625V		5		pF
		V <sub>DD</sub> = 3.465V, V <sub>DDO</sub> = 2.625V		3		pF
R <sub>OUT</sub>	Output Impedance	V <sub>DDO</sub> = 3.465V		15		Ω
		V <sub>DDO</sub> = 2.625V		17		Ω

## Function Table

**Table 3. OEx Function Table**

Inputs	Outputs
OE3, OE2, OE1, OE0	Q3, Q2, Q1, Q0
0	Hi-Z
1	Active (default)

NOTE: Asynchronous output enables.

## Absolute Maximum Ratings

NOTE: Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These ratings are stress specifications only. Functional operation of product at these conditions or any conditions beyond those listed in the *DC Characteristics* or *AC Characteristics* is not implied. Exposure to absolute maximum rating conditions for extended periods may affect product reliability.

Item	Rating
Supply Voltage, $V_{DD}$	4.6V
Inputs, $V_I$	-0.5V to $V_{DD} + 0.5V$
Outputs, $V_O$	-0.5V to $V_{DDO} + 0.5V$
Package Thermal Impedance, $\theta_{JA}$	100.3°C/W (0 mps)
Storage Temperature, $T_{STG}$	-65°C to 150°C

## DC Electrical Characteristics

**Table 4A. Power Supply DC Characteristics,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 3.3V \pm 5\%$  or  $2.5V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Power Supply Voltage		3.135	3.3	3.465	V
$V_{DDO}$	Output Supply Voltage		3.135	3.3	3.465	V
			2.375	2.5	2.625	V
$I_{DD}$	Power Supply Current			16	20	mA
$I_{DDO}$	Output Supply Current			6	10	mA

**Table 4B. Power Supply DC Characteristics,  $V_{DD} = 2.5V \pm 5\%$ ,  $V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$**

Symbol	Parameter	Test Conditions	Minimum	Typical	Maximum	Units
$V_{DD}$	Power Supply Voltage		2.375	2.5	2.625	V
$V_{DDO}$	Output Supply Voltage		2.375	2.5	2.625	V
$I_{DD}$	Power Supply Current			14	17	mA
$I_{DDO}$	Output Supply Current			5	10	mA

**Table 4C. LVCMOS/LVTTL DC Characteristics,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$** 

Symbol	Parameter		Test Conditions	Minimum	Typical	Maximum	Units
$V_{IH}$	Input High Voltage		$V_{DD} = 3.465\text{V}$	2		$V_{DD} + 0.3$	V
			$V_{DD} = 2.625\text{V}$	1.7		$V_{DD} + 0.3$	V
$V_{IL}$	Input Low Voltage		$V_{DD} = 3.465\text{V}$	-0.3		0.8	V
			$V_{DD} = 2.625\text{V}$	-0.3		0.7	V
$I_{IH}$	Input High Current	CLK	$V_{DD} = V_{IN} = 3.465\text{V}$ or $2.625\text{V}$			150	$\mu\text{A}$
		OE3, OE2, OE1, OE0	$V_{DD} = V_{IN} = 3.465\text{V}$ or $2.625\text{V}$			5	$\mu\text{A}$
$I_{IL}$	Input Low Current	CLK	$V_{DD} = 3.465\text{V}$ or $2.625\text{V}$ , $V_{IN} = 0\text{V}$	-5			$\mu\text{A}$
		OE3, OE2, OE1, OE0	$V_{DD} = 3.465\text{V}$ or $2.625\text{V}$ , $V_{IN} = 0\text{V}$	-150			$\mu\text{A}$
$V_{OH}$	Output High Voltage		$V_{DDO} = 3.3\text{V} \pm 5\%$ ; $I_{OH} = -12\text{mA}$	2.6			V
			$V_{DDO} = 2.5\text{V} \pm 5\%$ ; $I_{OH} = -12\text{mA}$	1.8			V
$V_{OL}$	Output Low Voltage		$V_{DDO} = 3.3\text{V} \pm 5\%$ ; $I_{OL} = 12\text{mA}$			0.5	V
			$V_{DDO} = 2.5\text{V} \pm 5\%$ ; $I_{OL} = 12\text{mA}$			0.5	V
$I_{OZL}$	Output Hi-Z Current Low			-5			$\mu\text{A}$
$I_{OZH}$	Output Hi-Z Current High					5	$\mu\text{A}$

## AC Electrical Characteristics

**Table 5A. AC Characteristics,  $V_{DD} = V_{DDO} = 3.3\text{V} \pm 5\%$ ,  $T_A = 0^\circ\text{C}$  to  $70^\circ\text{C}$** 

Parameter	Symbol		Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency					250	MHz
$t_{pLH}$	Propagation Delay, Low to High; NOTE 1	CLK		2.0	2.5	4.0	ns
$t_{sk(o)}$	Output Skew; NOTE 2, 5		Measured on the Rising Edge		30	60	ps
$t_{sk(pp)}$	Part-to-Part Skew; NOTE 3, 5					400	ps
$t_R / t_F$	Output Rise/Fall Time		20% to 80%	400	600	1000	ps
odc	Output Duty Cycle		Output Frequency < 150MHz	45	50	55	%
			Output Frequency $\geq 150\text{MHz}$	40	47	60	%
$t_{EN}$	Output Enable Time; NOTE 4				3	5	ns
$t_{DIS}$	Output Disable Time; NOTE 4				4	6	ns

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lpm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

NOTE 1: Measured from the  $V_{DD}/2$  of the input to  $V_{DDO}/2$  of the output.

NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 3: Defined as skew between outputs on different devices operating at the same supply voltage, same frequency, same temperature and with equal load conditions. Using the same type of input on each device, the output is measured at  $V_{DDO}/2$ .

NOTE 4: These parameters are guaranteed by characterization. Not tested in production.

NOTE 5: This parameter is defined in accordance with JEDEC Standard 65.

**Table 5B. AC Characteristics,  $V_{DD} = V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency				250	MHz
$t_{PLH}$	Propagation Delay, Low to High; NOTE 1	CLK	2.0	2.7	4.0	ns
$t_{sk(o)}$	Output Skew; NOTE 2, 5	Measured on the Rising Edge		30	60	ps
$t_{sk(pp)}$	Part-to-Part Skew; NOTE 3, 5				425	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	400	750	1200	ps
odc	Output Duty Cycle	Output Frequency < 150MHz	45	50	55	%
		Output Frequency $\geq$ 150MHz	40	47	60	%
$t_{EN}$	Output Enable Time; NOTE 4			3	5	ns
$t_{DIS}$	Output Disable Time; NOTE 4			4	6	ns

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

NOTE 1: Measured from the  $V_{DD}/2$  of the input to  $V_{DDO}/2$  of the output.

NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 3: Defined as skew between outputs on different devices operating at the same supply voltage, same frequency, same temperature and with equal load conditions. Using the same type of input on each device, the output is measured at  $V_{DDO}/2$ .

NOTE 4: These parameters are guaranteed by characterization. Not tested in production.

NOTE 5: This parameter is defined in accordance with JEDEC Standard 65.

**Table 5C. AC Characteristics,  $V_{DD} = 3.3V \pm 5\%$ ,  $V_{DDO} = 2.5V \pm 5\%$ ,  $T_A = 0^\circ C$  to  $70^\circ C$** 

Parameter	Symbol	Test Conditions	Minimum	Typical	Maximum	Units
$f_{OUT}$	Output Frequency				250	MHz
$t_{PLH}$	Propagation Delay, Low to High; NOTE 1	CLK	2.0	2.8	4.0	ns
$t_{sk(o)}$	Output Skew; NOTE 2, 5	Measured on the Rising Edge		30	60	ps
$t_{sk(pp)}$	Part-to-Part Skew; NOTE 3, 5				425	ps
$t_R / t_F$	Output Rise/Fall Time	20% to 80%	400	750	1200	ps
odc	Output Duty Cycle	Output Frequency < 150MHz	45	50	55	%
		Output Frequency $\geq$ 150MHz	40	47	60	%
$t_{EN}$	Output Enable Time; NOTE 4			3	5	ns
$t_{DIS}$	Output Disable Time; NOTE 4			4	6	ns

NOTE: Electrical parameters are guaranteed over the specified ambient operating temperature range, which is established when the device is mounted in a test socket with maintained transverse airflow greater than 500 lfm. The device will meet specifications after thermal equilibrium has been reached under these conditions.

NOTE 1: Measured from the  $V_{DD}/2$  of the input to  $V_{DDO}/2$  of the output.

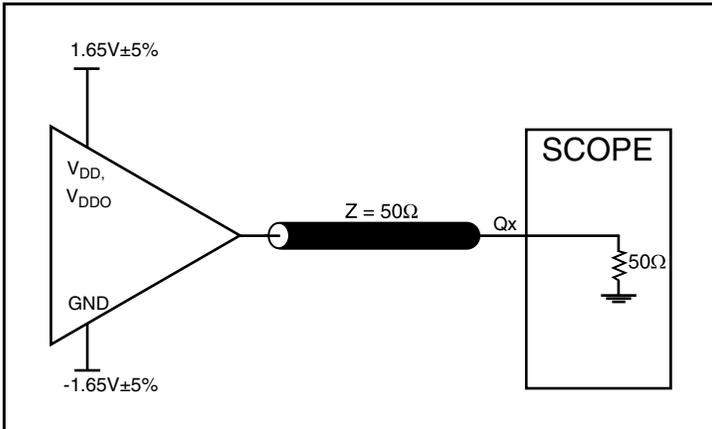
NOTE 2: Defined as skew between outputs at the same supply voltage and with equal load conditions. Measured at  $V_{DDO}/2$ .

NOTE 3: Defined as skew between outputs on different devices operating at the same supply voltage, same frequency, same temperature and with equal load conditions. Using the same type of input on each device, the output is measured at  $V_{DDO}/2$ .

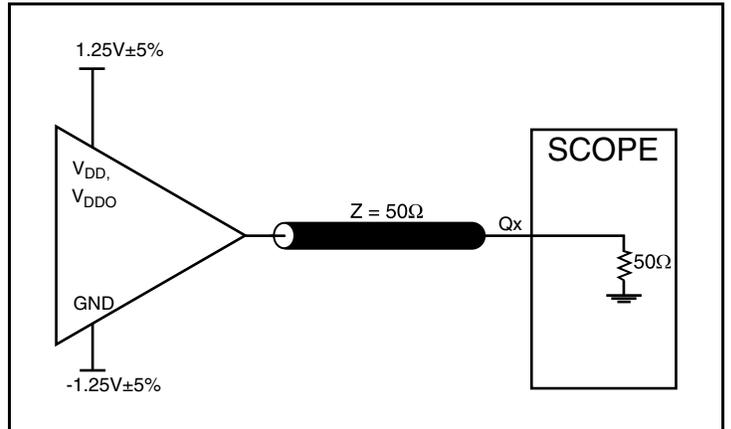
NOTE 4: These parameters are guaranteed by characterization. Not tested in production.

NOTE 5: This parameter is defined in accordance with JEDEC Standard 65.

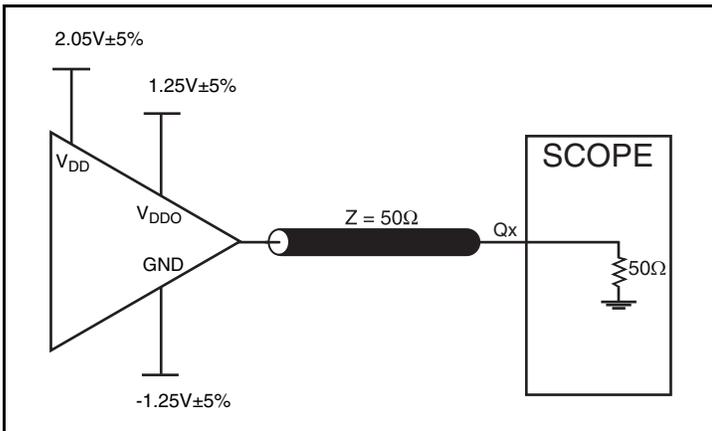
## Parameter Measurement Information



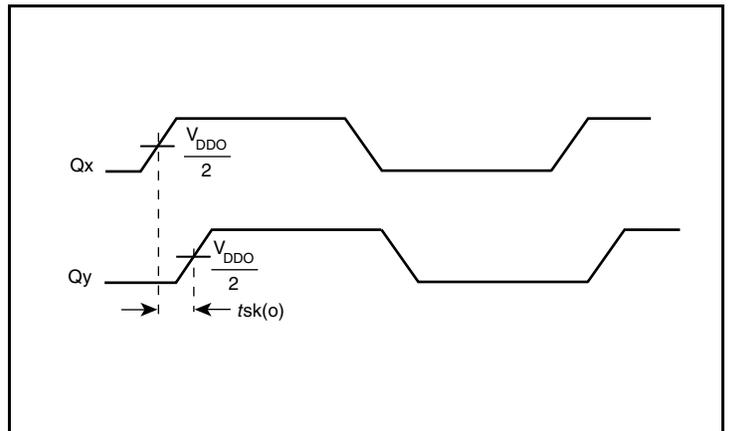
3.3V Core/3.3V LVCMOS Output Load Test Circuit



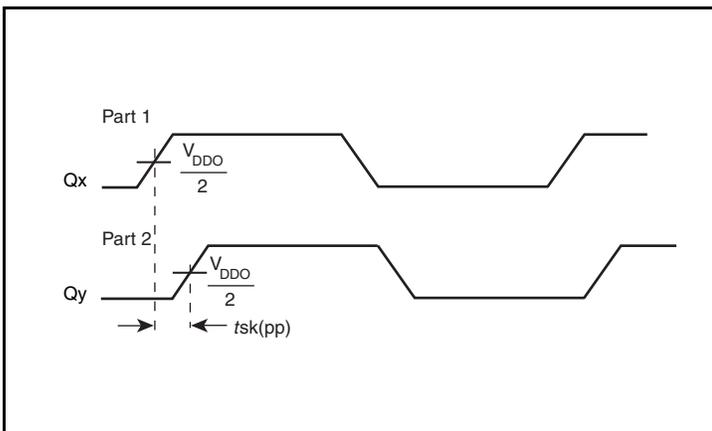
2.5V Core/2.5V LVCMOS Output Load Test Circuit



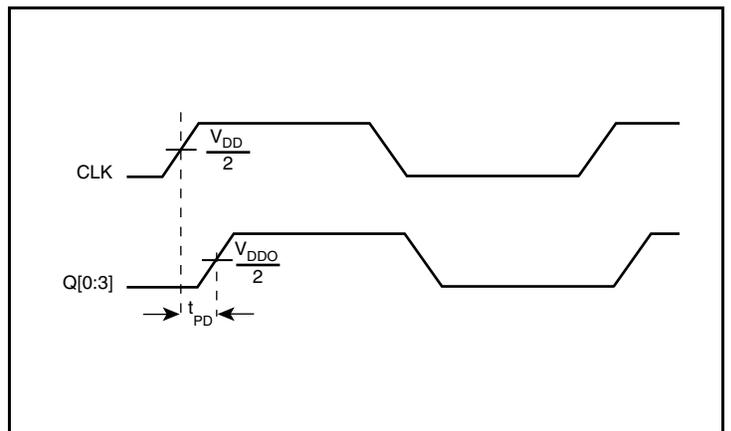
3.3V Core/2.5V LVCMOS Output Load Test Circuit



Output Skew

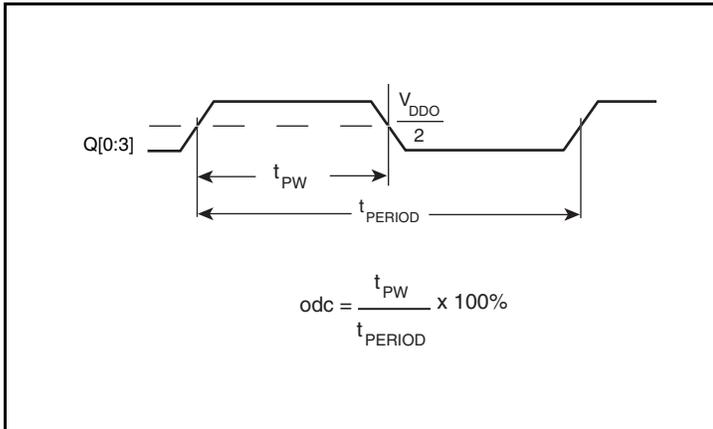


Part-to-Part Skew

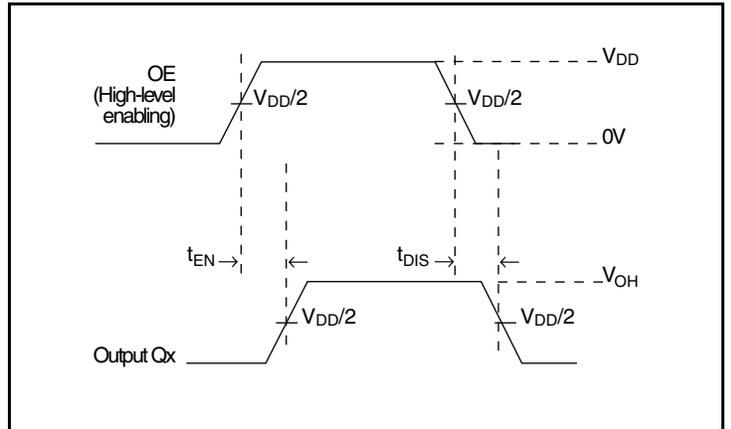


Propagation Delay

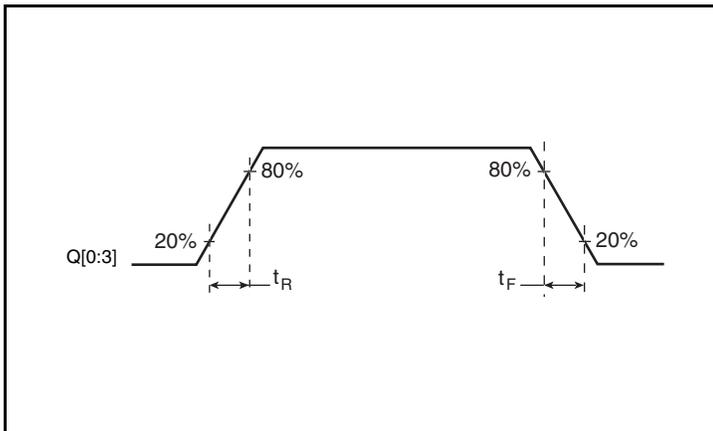
Parameter Measurement Information, continued



Output Duty Cycle/Pulse Width/Period



Output Enable/Disable Time



Output Rise/Fall Time

## Applications Information

### Recommendations for Unused Input and Output Pins

#### Inputs:

##### LVC MOS Control Pins

All control pins have internal pullup resistors; additional resistance is not required but can be added for additional protection. A 1k $\Omega$  resistor can be used.

#### Outputs:

##### LVC MOS Outputs

All unused LVC MOS outputs can be left floating. There should be no trace attached.

## Power Considerations

This section provides information on power dissipation and junction temperature for the ICS8304-02. Equations and example calculations are also provided.

### 1. Power Dissipation.

The total power dissipation for the ICS8304-02 is the sum of the core power plus the power dissipated due to loading. The following is the power dissipation for  $V_{DD} = 3.3V + 5\% = 3.465V$ , which gives worst case results.

- Power (core)<sub>MAX</sub> =  $V_{DD\_MAX} * (I_{DD} + I_{DDO}) = 3.465V * (20mA + 17mA) = \mathbf{128.21mW}$
- Output Impedance  $R_{OUT}$  Current due to Loading  $50\Omega$  to  $V_{DD}/2$   
Output Current  $I_{OUT} = V_{DD\_MAX} / [2 * (50\Omega + R_{OUT})] = 3.465V / [2 * (50\Omega + 15\Omega)] = \mathbf{26.7mA}$
- Power Dissipation on the  $R_{OUT}$  per LVCMOS output  
Power ( $R_{OUT}$ ) =  $R_{OUT} * (I_{OUT})^2 = 15\Omega * (26.7mA)^2 = \mathbf{10.7mW}$  per output
- Total Power ( $R_{OUT}$ ) =  $10.7mW * 4 = \mathbf{42.8mW}$

### Dynamic Power Dissipation at 250MHz

$$\text{Power (250MHz)} = C_{PD} * \text{Frequency} * (V_{DD})^2 = 5pF * 250MHz * (3.465V)^2 = \mathbf{15mW}$$
 per output

$$\text{Total Power (250MHz)} = 15mW * 4 = \mathbf{60mW}$$

### Total Power Dissipation

- **Total Power**  
= Power (core)<sub>MAX</sub> + Power ( $R_{OUT}$ ) + Power (250MHz)  
=  $128.21mW + 42.8mW + 60mW$   
= **231.01mW**

### 2. Junction Temperature.

Junction temperature,  $T_j$ , is the temperature at the junction of the bond wire and bond pad directly affects the reliability of the device. The maximum recommended junction temperature is  $125^\circ\text{C}$ . Limiting the internal transistor junction temperature,  $T_j$ , to  $125^\circ\text{C}$  ensures that the bond wire and bond pad temperature remains below  $125^\circ\text{C}$ .

The equation for  $T_j$  is as follows:  $T_j = \theta_{JA} * Pd\_total + T_A$

$T_j$  = Junction Temperature

$\theta_{JA}$  = Junction-to-Ambient Thermal Resistance

$Pd\_total$  = Total Device Power Dissipation (example calculation is in section 1 above)

$T_A$  = Ambient Temperature

In order to calculate junction temperature, the appropriate junction-to-ambient thermal resistance  $\theta_{JA}$  must be used. Assuming no air flow and a multi-layer board, the appropriate value is  $100.3^\circ\text{C/W}$  per Table 6 below.

Therefore,  $T_j$  for an ambient temperature of  $70^\circ\text{C}$  with all outputs switching is:

$$70^\circ\text{C} + 0231W * 100.3^\circ\text{C/W} = 93.17^\circ\text{C}. \text{ This is below the limit of } 125^\circ\text{C}.$$

This calculation is only an example.  $T_j$  will obviously vary depending on the number of loaded outputs, supply voltage, air flow and the type of board (multi-layer).

**Table 6. Thermal Resistance  $\theta_{JA}$  for 16 Lead TSSOP, Forced Convection**

$\theta_{JA}$ by Velocity			
Meters per Second	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	$100.3^\circ\text{C/W}$	$96.0^\circ\text{C/W}$	$93.9^\circ\text{C/W}$

## Reliability Information

Table 7.  $\theta_{JA}$  vs. Air Flow Table for a 16 Lead TSSOP

$\theta_{JA}$ vs. Air Flow			
Meters per Second	0	1	2.5
Multi-Layer PCB, JEDEC Standard Test Boards	100.3°C/W	96.0°C/W	93.9°C/W

## Transistor Count

The transistor count for ICS8304-02: 2690

## Package Outline and Package Dimensions

Package Outline - G Suffix for 16 Lead TSSOP

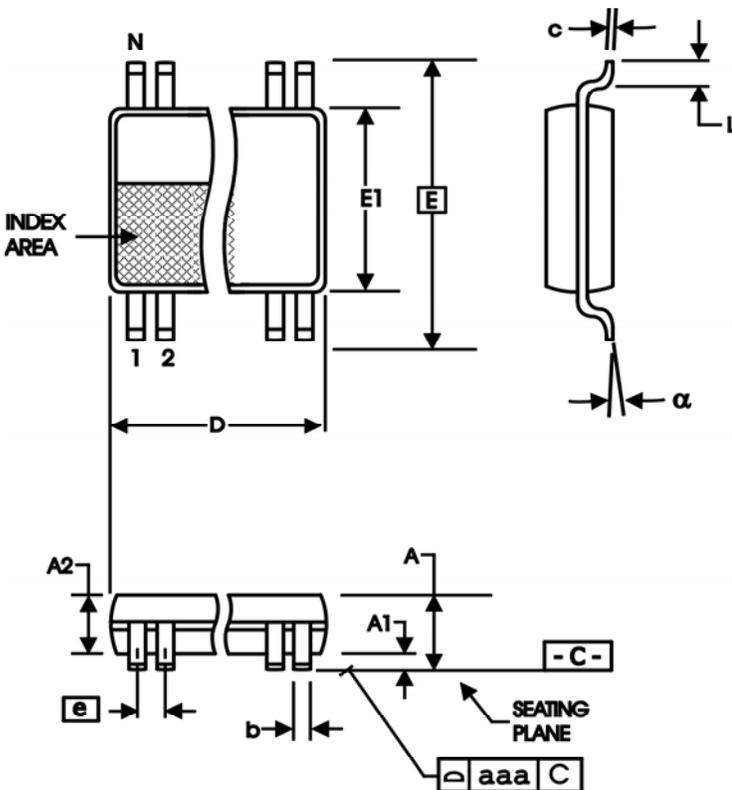


Table 8. Package Dimensions for 16 Lead TSSOP

All Dimensions in Millimeters		
Symbol	Minimum	Maximum
N	16	
A		1.20
A1	0.05	0.15
A2	0.80	1.05
b	0.19	0.30
c	0.09	0.20
D	4.90	5.10
E	6.40 Basic	
E1	4.30	4.50
e	0.65 Basic	
L	0.45	0.75
$\alpha$	0°	8°
aaa		0.10

Reference Document: JEDEC Publication 95, MO-153

## Ordering Information

Table 9. Ordering Information

Part/Order Number	Marking	Package	Shipping Packaging	Temperature
8304AG-02LF	8304A02L	"Lead-Free" 16 Lead TSSOP	Tube	0°C to 70°C
8304AG-02LFT	8304A02L	"Lead-Free" 16 Lead TSSOP	Tape & Reel	0°C to 70°C

## Revision History

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Revision Date	Description of Change
May 6, 2016	<ul style="list-style-type: none"><li>▪ Product Discontinuation Notice - Last time buy expires May 6, 2017.</li><li>▪ PDN CQ-16-01</li></ul>



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